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Harel

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(54) **GAIN MEASUREMENT OF DISTRIBUTED ANTENNA SYSTEM (DAS) SEGMENTS DURING ACTIVE COMMUNICATIONS EMPLOYING AUTOCORRELATION ON A COMBINED TEST SIGNAL AND COMMUNICATIONS SIGNAL**

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CPC ***H04W 52/241*** (2013.01); *H04W 52/243* (2013.01)

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CPC H04W 24/00; H04W 24/08; H04W 88/08
USPC 455/424, 423, 425, 422.1, 403
See application file for complete search history.

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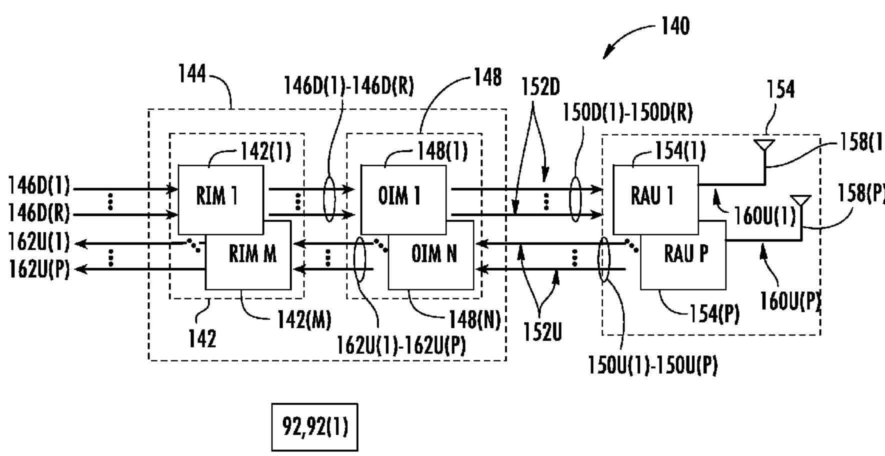
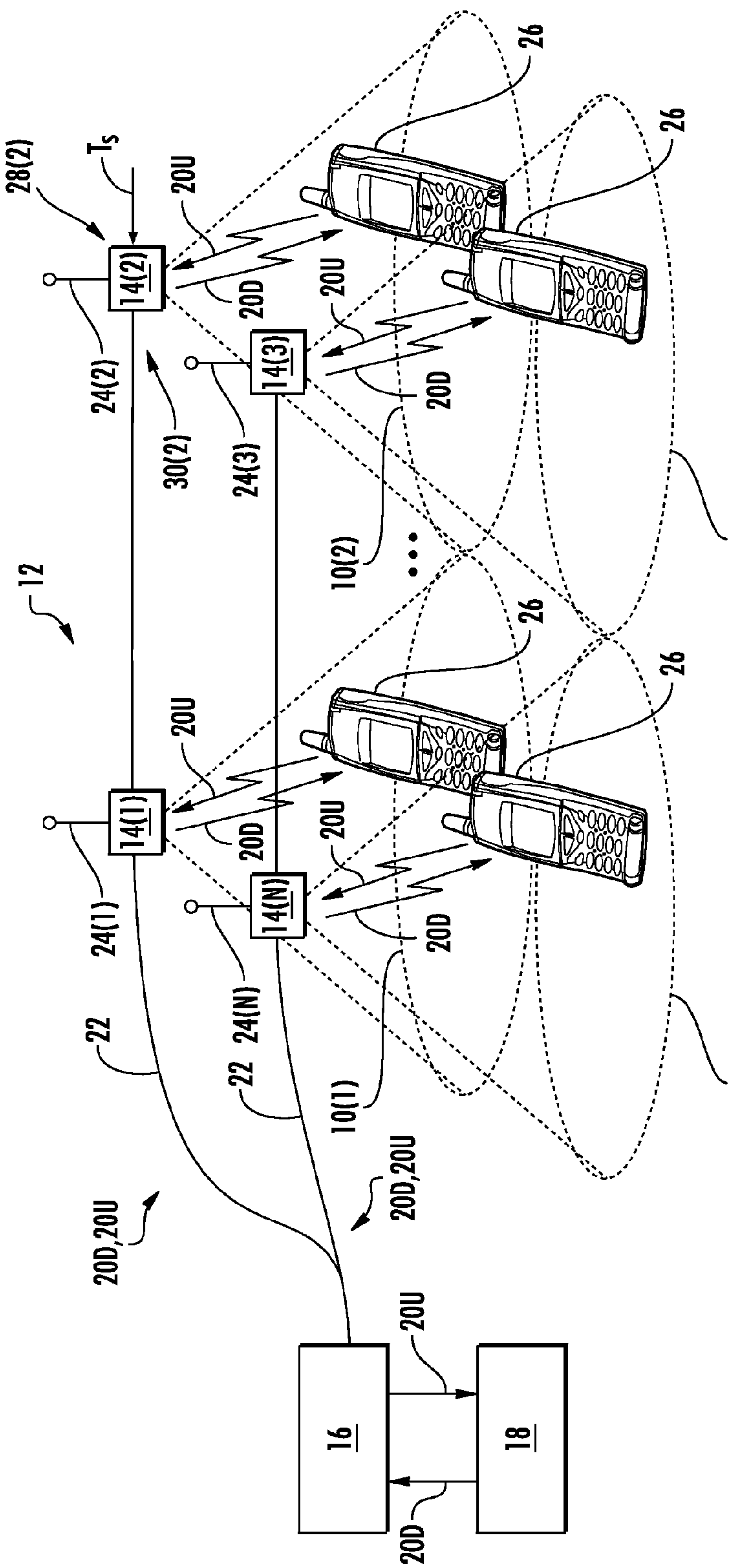
(57) **ABSTRACT**

Gain measurement of distributed antenna system (DAS) segments during active communications employing autocorrelation on a combined test signal and communications signal is disclosed. In one embodiment, a test signal is injected into one or more DAS segments in a DAS. The test signal power is measured at the input and output of the DAS segment(s) for which gain measurement is desired. The difference in power of the test signal between the input and the output of the DAS segment is the gain of the DAS segment. The frequency of the test signal is provided to be within the frequency band of the communications service signals supported by the DAS segment. To allow for gain measurement of a DAS segment during active communication periods when the DAS segment is actively transmitting communications service signals, autocorrelation is employed to separate the test signal from combined test signal and communications service signals.

26 Claims, 8 Drawing Sheets

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14(N)
20U
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24(3)
24(N)
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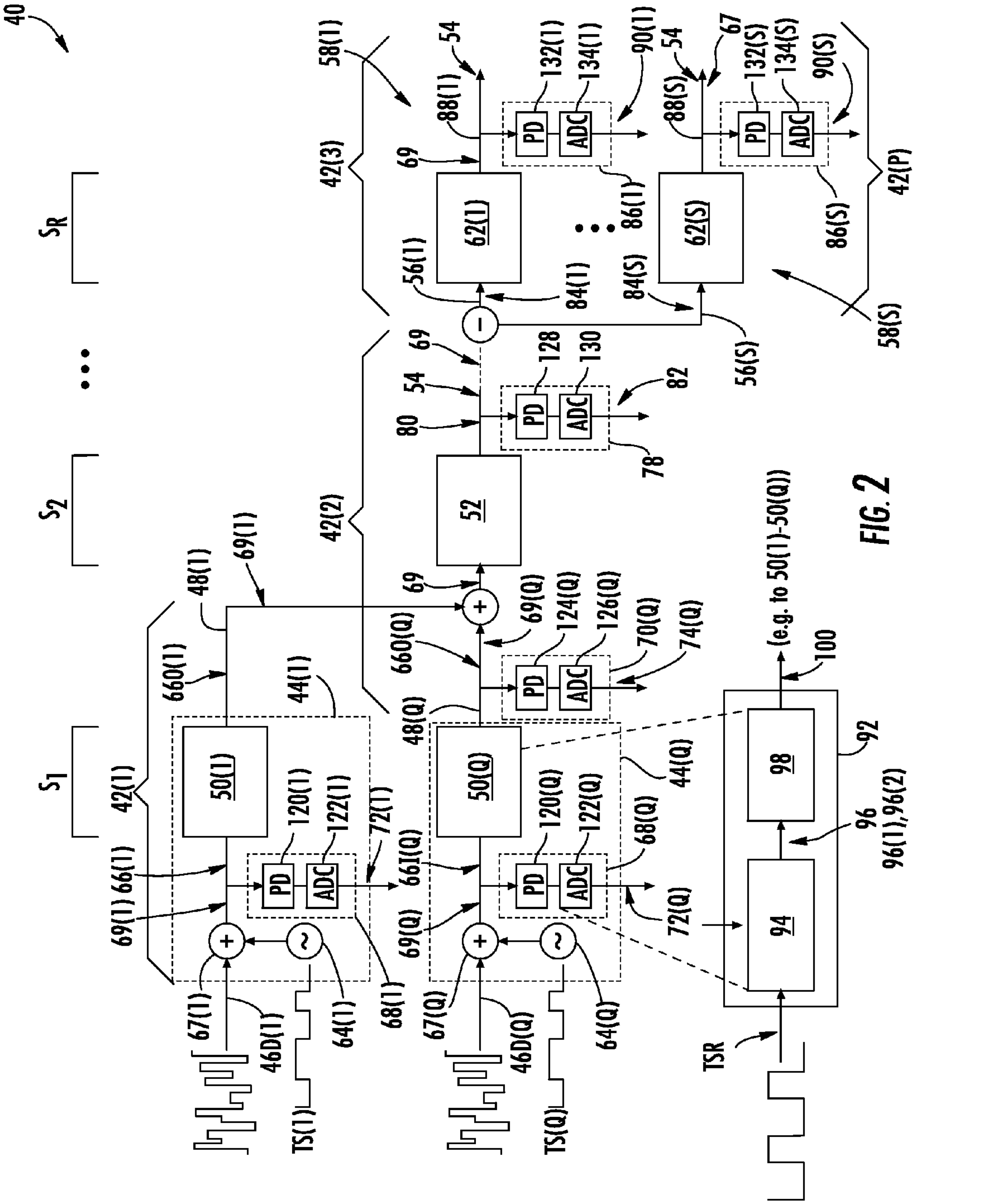
30(2)
10(1)
10(2)
10(3)
10(N)
22
20D,20U
16
18

FIG. 1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S_2
S_R
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42(2)
42(3)
42(P)
50(1)
50(Q)
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62(1)
62(S)
94
98
92
96
96(1),96(2)
100
(e.g. to 50(1)-50(Q))
PD
ADC
TS(1)
TS(Q)
TSR
46D(1)
46D(Q)
67(1)
67(Q)
64(1)
64(Q)
68(1)
68(Q)
69(1)
69(Q)
66(1)
66I(Q)
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66O(Q)
48(1)
48(Q)
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128
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88(1)
88(S)
86(1)
86(S)
90(1)
90(S)
132(1)
134(1)
132(S)
134(S)
67

FIG. 2

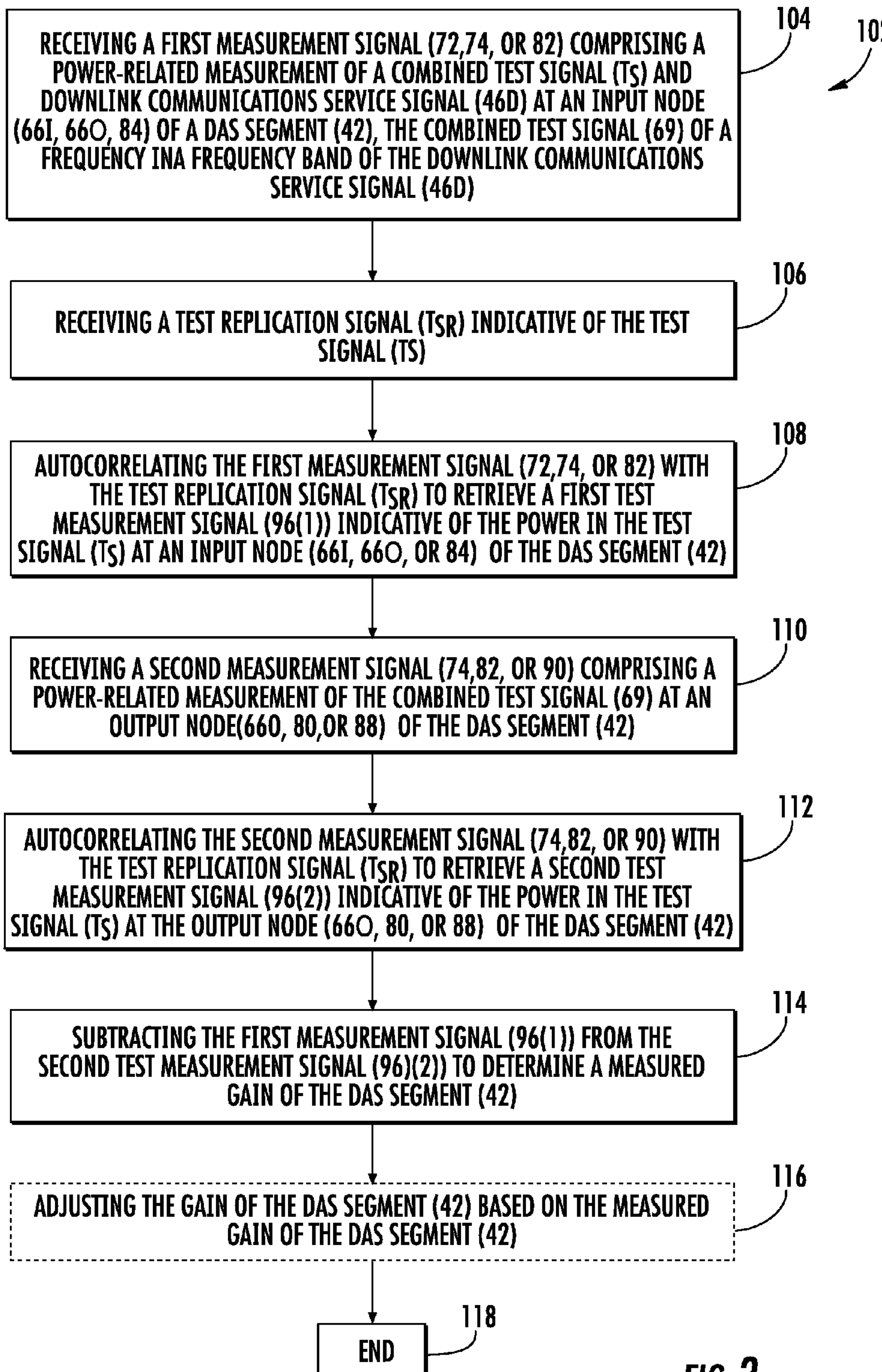

102
104
RECEIVING A FIRST MEASUREMENT SIGNAL (72,74, OR 82) COMPRISING A POWER-RELATED MEASUREMENT OF A COMBINED TEST SIGNAL (TS) AND DOWNLINK COMMUNICATIONS SERVICE SIGNAL (46D) AT AN INPUT NODE (66I, 66O, 84) OF A DAS SEGMENT (42), THE COMBINED TEST SIGNAL (69) OF A FREQUENCY INA FREQUENCY BAND OF THE DOWNLINK COMMUNICATIONS SERVICE SIGNAL (46D)
106
RECEIVING A TEST REPLICATION SIGNAL (TSR) INDICATIVE OF THE TEST SIGNAL (TS)
108
AUTOCORRELATING THE FIRST MEASUREMENT SIGNAL (72,74, OR 82) WITH THE TEST REPLICATION SIGNAL (TSR) TO RETRIEVE A FIRST TEST MEASUREMENT SIGNAL (96(1)) INDICATIVE OF THE POWER IN THE TEST SIGNAL (TS) AT AN INPUT NODE (66I, 66O, OR 84) OF THE DAS SEGMENT (42)
110
RECEIVING A SECOND MEASUREMENT SIGNAL (74,82, OR 90) COMPRISING A POWER-RELATED MEASUREMENT OF THE COMBINED TEST SIGNAL (69) AT AN OUTPUT NODE(66O, 80,OR 88) OF THE DAS SEGMENT (42)
112
AUTOCORRELATING THE SECOND MEASUREMENT SIGNAL (74,82, OR 90) WITH THE TEST REPLICATION SIGNAL (TSR) TO RETRIEVE A SECOND TEST MEASUREMENT SIGNAL (96(2)) INDICATIVE OF THE POWER IN THE TEST SIGNAL (TS) AT THE OUTPUT NODE (66O, 80, OR 88) OF THE DAS SEGMENT (42)
114
SUBTRACTING THE FIRST MEASUREMENT SIGNAL (96(1)) FROM THE SECOND TEST MEASUREMENT SIGNAL (96)(2)) TO DETERMINE A MEASURED GAIN OF THE DAS SEGMENT (42)
116
ADJUSTING THE GAIN OF THE DAS SEGMENT (42) BASED ON THE MEASURED GAIN OF THE DAS SEGMENT (42)
118
END

FIG. 3

136

DIGITAL VALUE (137)	POWER(mA) (138)
00000000	0
00000001	0.02VA
⋮	⋮
11111110	4.98VA
11111111	5VA

FIG. 4

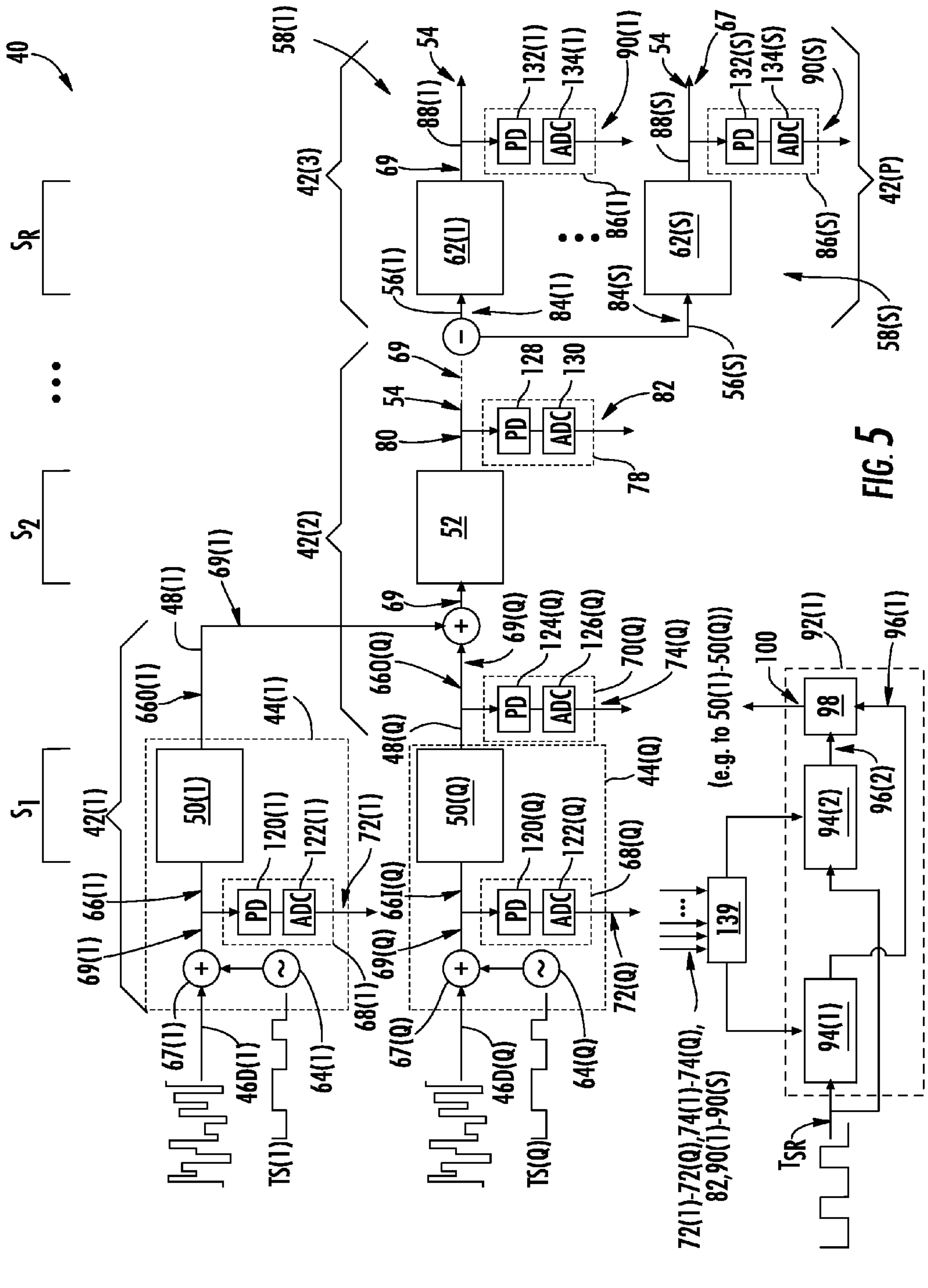
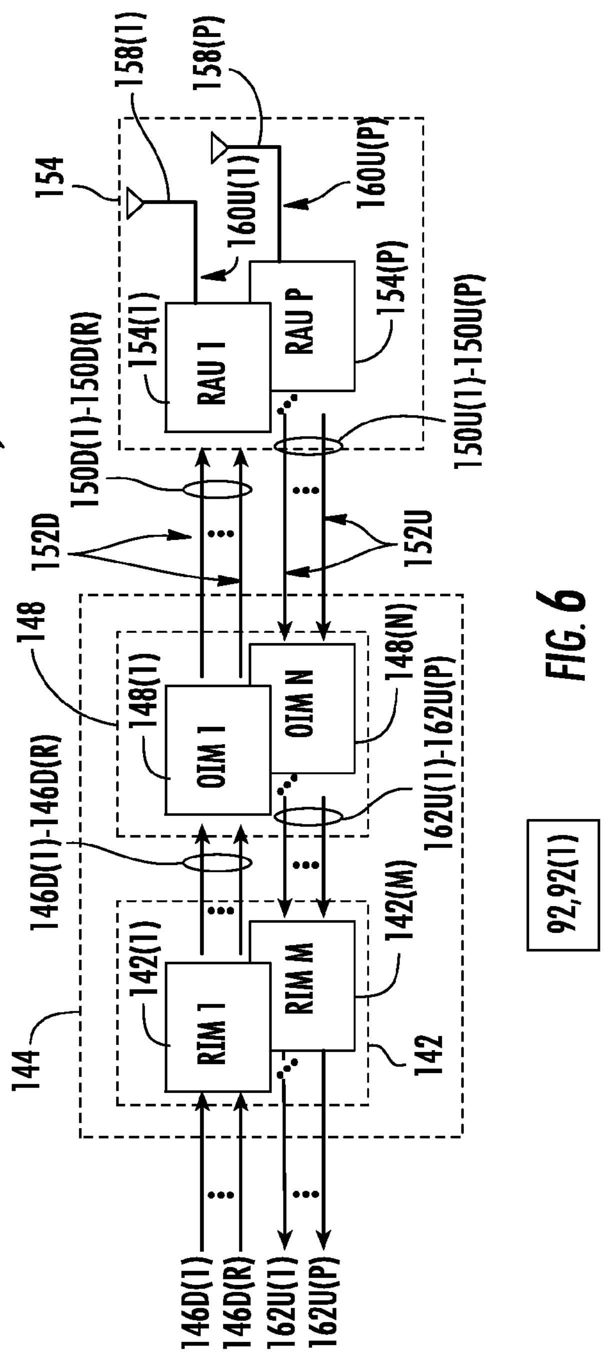


FIG. 5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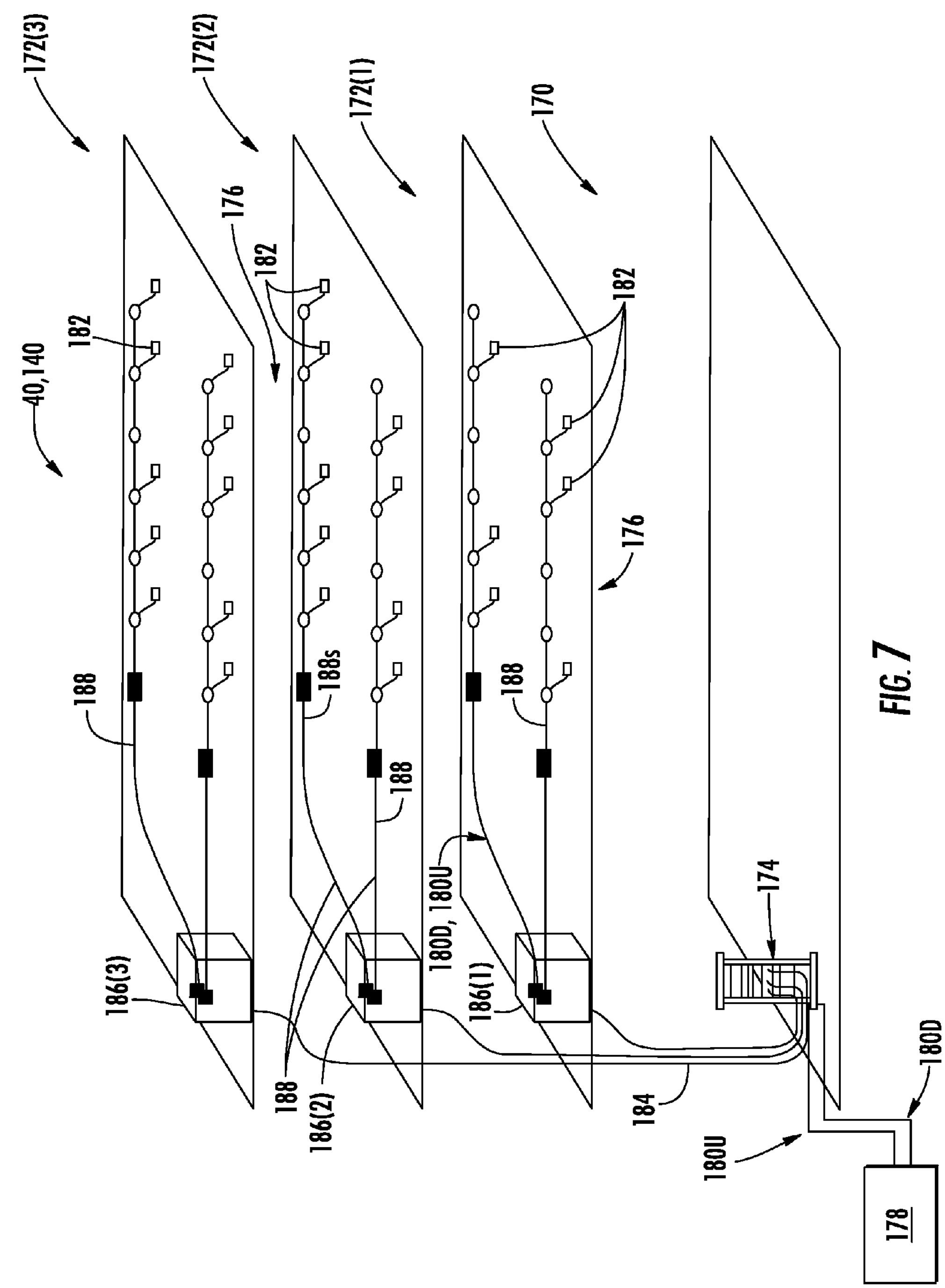
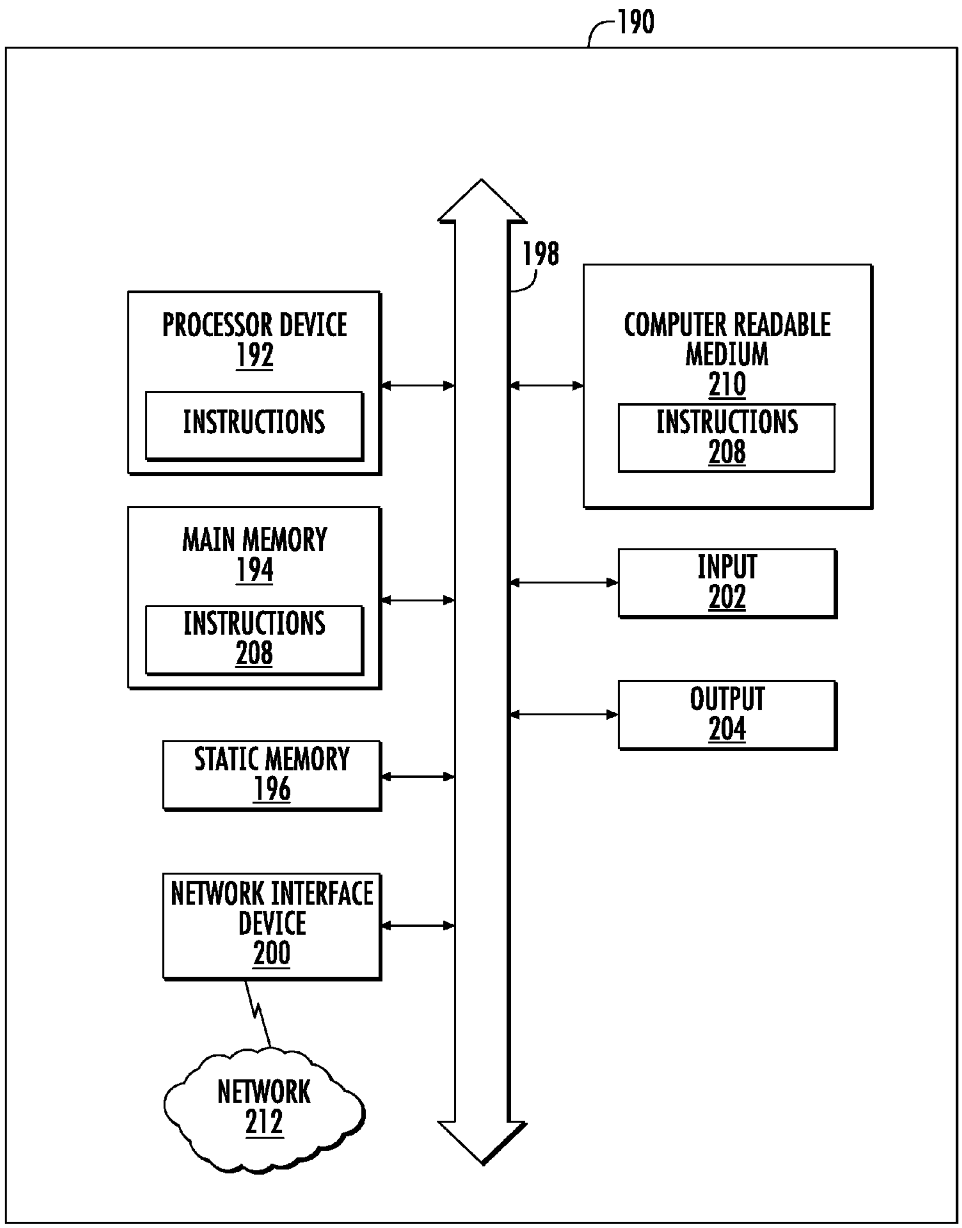
154
158(1)
158(P)
160U(1)
160U(P)
154(1)
RAU 1
RAU P
154(P)
150D(1)-150D(R)
150U(1)-150U(P)
152D
152U
148
148(1)
OIM 1
OIM N
148(N)
146D(1)-146D(R)
162U(1)-162U(P)
144
142(1)
RIM 1
RIM M
142(M)
142
146D(1)
146D(R)
162U(1)
162U(P)
92,92(1)

FIG. 6



172(3)
172(2)
172(1)
170
40,140
176
182
188
188s
180D, 180U
186(3)
186(2)
186(1)
174
184
180D
180U
178

FIG. 7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198
PROCESSOR DEVICE
192
INSTRUCTIONS
MAIN MEMORY
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INSTRUCTIONS
208
STATIC MEMORY
196
NETWORK INTERFACE
DEVICE
200
NETWORK
212
COMPUTER READABLE
MEDIUM
210
INSTRUCTIONS
208
INPUT
202
OUTPUT
204

FIG. 8

GAIN MEASUREMENT OF DISTRIBUTED ANTENNA SYSTEM (DAS) SEGMENTS DURING ACTIVE COMMUNICATIONS EMPLOYING AUTOCORRELATION ON A COMBINED TEST SIGNAL AND COMMUNICATIONS SIGNAL

BACKGROUND

The technology of the present disclosure relates generally to distributed antenna systems (DASs) that support distributing communications services to remote antenna units, and particularly to measuring gain of DAS sub-systems within the DAS.

Wireless communication is rapidly growing, with ever-increasing demands for high-speed mobile data communication. As an example, local area wireless services (e.g., so-called "wireless fidelity" or "WiFi" systems) and wide area wireless services are being deployed in many different types of areas (e.g., coffee shops, airports, libraries, etc.). Distributed communications or antenna systems communicate with wireless devices called "clients," "client devices," or "wireless client devices," which must reside within the wireless range or "cell coverage area" in order to communicate with an access point device. Distributed antenna systems are particularly useful to be deployed inside buildings or other indoor environments where client devices may not otherwise be able to effectively receive radio-frequency (RF) signals from a source, such as a base station for example. Example applications where distributed antenna systems can be used to provide or enhance coverage for wireless services include public safety, cellular telephony, wireless local access networks (LANs), location tracking, and medical telemetry inside buildings and over campuses.

One approach to deploying a distributed antenna system involves the use of RF antenna coverage areas, also referred to as "antenna coverage areas." Antenna coverage areas can be formed by remotely distributed antenna units, also referred to as remote units (RUs). The remote units each contain or are configured to couple to one or more antennas configured to support the desired frequency(ies) or polarization to provide the antenna coverage areas. Antenna coverage areas can have a radius in the range from a few meters up to twenty meters as an example. Combining a number of remote units creates an array of antenna coverage areas. Because the antenna coverage areas each cover small areas, there typically may be only a few users (clients) per antenna coverage area. This arrangement generates a uniform high quality signal enabling high throughput supporting the required capacity for the wireless system users.

As an example, FIG. **1** illustrates distribution of communications services to coverage areas **10**(**1**)-**10**(N) of a DAS **12**, wherein 'N' is the number of coverage areas. These communications services can include cellular services, wireless services such as RFID tracking, Wireless Fidelity (WiFi), local area network (LAN), WLAN, and combinations thereof, as examples. The coverage areas **10**(**1**)-**10**(N) may be remotely located. In this regard, the remote coverage areas **10**(**1**)-**10**(N) are created by and centered on remote antenna units **14**(**1**)-**14**(N) connected to a central unit **16** (e.g., a head-end controller or head-end unit). The central unit **16** may be communicatively coupled to a base station **18**. In this regard, the central unit **16** receives downlink communications signals **20**D from the base station **18** to be distributed to the remote antenna units **14**(**1**)-**14**(N). The remote antenna units **14**(**1**)-**14**(N) are configured to receive downlink communications signals **20**D from the central unit **16** over a communications medium **22** to be distributed to the respective coverage areas **10**(**1**)-**10**(N) of the remote antenna units **14**(**1**)-**14**(N). Each remote antenna unit **14**(**1**)-**14**(N) may include an RF transmitter/receiver (not shown) and a respective antenna **24**(**1**)-**24**(N) operably connected to the RF transmitter/receiver to wirelessly distribute the communications services to client devices **26** within their respective coverage areas **10**(**1**)-**10**(N). The remote antenna units **14**(**1**)-**14**(N) are also configured to receive uplink communications signals **20**U from the client devices **26** in their respective coverage areas **10**(**1**)-**10**(N) to be distributed to the base station **18**. The size of a given coverage area **10**(**1**)-**10**(N) is determined by the amount of RF power transmitted by the respective remote antenna unit **14**(**1**)-**14**(N), the receiver sensitivity, antenna gain and the RF environment, as well as by the RF transmitter/receiver sensitivity of the client device **26**. Client devices **26** usually have a fixed RF receiver sensitivity, so that the above-mentioned properties of the remote antenna units **14**(**1**)-**14**(N) mainly determine the size of their respective remote coverage areas **10**(**1**)-**10**(N).

It may be desired to measure gain (i.e., attenuation) of the sub-systems of the DAS **12** in FIG. **1** to determine performance degradation. For example, the gain of the central unit **16** and/or the remote antenna unit **14**, as DAS sub-systems, may be significantly different from their nominal gain level due to component variance, temperature changes, aging, and/or loading conditions. In this example, the central unit **16** and/or the remote antenna units **14**(**1**)-**14**(N) may include an attenuator (not shown) that can be adjusted to adjust the actual gain back to the desired nominal gain level. In this regard, as an example, when the DAS **12** in FIG. **1** is first installed and all elements are interconnected and operated, it may be desired to measure the gain of each relevant DAS **12** segment. Corrective actions, such as gain adjustment, can be taken based on the measured gain of the DAS **12** segments. For example, the uplink gain of the remote antenna unit **14**(**2**) in the DAS **12** in FIG. **1** may be measured by injecting a test signal Ts at an uplink input **28**(**2**) and measuring the power of the test signal Ts at the uplink input **28**(**2**) and an uplink output **30**(**2**). So that the test signal Ts is provided in a frequency band that is supported for transmission in the remote antenna unit **14**(**2**), the test signal Ts is provided in a common frequency band with the supported uplink communications signals **20**U (i.e., a communications service signal). The uplink gain of the remote antenna unit **14**(**2**) can be determined by subtracting the power of the test signal Ts at uplink input **28**(**2**) from the power of the test signal Ts at the uplink output **30**(**2**).

This method of gain measurement has a significant disadvantage. This method does not allow measuring gain of a DAS segment while the DAS is actively transferring communications service signals. The test signal, being in a common frequency band with a communications service signal, might interfere with the communications service signal. In addition, the communications service signal might disturb the test signal. A test signal in a different frequency band from the supported communications service signals may be employed for gain measurement to prevent the test signal from interfering communications service signals. However, in this scenario, the DAS segment would have to support the additional frequency band of the test signal and employ appropriate filters to filter the test signal from the communications service signals, thus adding additional cost and complexity to the DAS components in the DAS. However, because the gain of the DAS might be different at each frequency due to the frequency dependent response of the DAS components, an accurate gain measurement may only be possible using a test signal that has a frequency in a frequency band of a supported communications service signals in the DAS.

No admission is made that any reference cited herein constitutes prior art. Applicant expressly reserves the right to challenge the accuracy and pertinency of any cited documents.

SUMMARY

Embodiments disclosed herein include gain measurement of distributed antenna system (DAS) segments during active communications employing autocorrelation on a combined test signal and communications signal. Related devices, systems, and methods are also disclosed. In this regard, in one embodiment, a test signal is injected into one or more DAS segments in a DAS. The power of the test signal is measured at the input and output of a given DAS segment for which gain measurement is desired. The difference in power of the test signal between the input and the output of the DAS segment is the gain (or attenuation) of the DAS segment. The frequency of the test signal is provided to be within a frequency band of the communications service signals supported by the DAS segment so that the DAS segment can transmit the frequency band of the communications service signals and can also transmit the test signal. Further, to allow for gain measurement of a DAS segment during active communication periods when the DAS segment is actively transmitting communications service signals, autocorrelation is employed to separate the test signal from combined test signal and communications service signals transmitted by the DAS segment. In this manner, gain measurements of the test signal can be obtained to determine the gain of the DAS segment even though the test signal and communications service signals are combined in the DAS segment.

One embodiment of the disclosure relates to a DAS segment gain measurement system. The DAS segment gain measurement system comprises a signal correlator. The signal correlator is configured to receive a first measurement signal comprising a power-related measurement of a combined test signal and communications service signal at an input node of a DAS segment, the combined test signal of a frequency in a frequency band of the communications service signal. The signal correlator is also configured to receive a test replication signal indicative of the test signal. The signal correlator is also configured to autocorrelate the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment. The signal correlator is also configured to provide the first test measurement signal at the input node to a controller. The signal correlator is also configured to receive a second measurement signal comprising a power-related measurement of the combined test signal at an output node of the DAS segment. The signal correlator is also configured to autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment. The signal correlator is also configured to provide the second test measurement signal at the input node to a controller. The DAS segment gain measurement system also comprises a controller. The controller is configured to receive the first test measurement signal. The controller is also configured to receive the second test measurement signal. The controller is also configured to subtract the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment. The controller can be configured to adjust the gain of the DAS segment based on the measured gain of the DAS segment.

Another embodiment of the disclosure relates to a method of measuring gain in a distributed antenna system (DAS) segment. The method comprises receiving a first measurement signal comprising a power-related measurement of a combined test signal and communications service signal at an input node of a DAS segment, the combined test signal of a frequency in a frequency band of the communications service signal. The method also comprises receiving a test replication signal indicative of the test signal. The method also comprises autocorrelating the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment. The method also comprises receiving a second measurement signal comprising a power-related measurement of the combined test signal at an output node of the DAS segment. The method also comprises autocorrelating the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment. The method also comprises subtracting the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment. The method can also comprise adjusting the gain of the DAS segment based on the measured gain of the DAS segment.

Another embodiment of the disclosure relates to DAS. The DAS comprises a plurality of DAS segments each configured to distribute communications service signals by being configured to distribute downlink communications service signals towards a plurality of remote antenna units and distribute uplink communications service signals received from client devices towards a central unit. The plurality of DAS segments each comprising an input node and an output node. The DAS also comprises a test signal generator. The test signal generator is configured to generate a test signal of a frequency in a frequency band of the communications service signals. The test signal generator is also configured to inject the test signal to the input node of the plurality of DAS segments. The DAS also comprises a plurality of power detection circuits each coupled to an input node or an output node of a DAS segment. Each of the plurality of power detection circuits configured to detect a power-related measurement of combined test signal and communications service signal, and provide a measurement signal comprising a power-related measurement of a combined test signal and communications service signal. The DAS also comprises a signal switch. The signal switch is configured to receive a plurality of the measurement signals from each of the plurality of power detection circuits, and selectively provide a measurement signal from a plurality of the power-related measurements of the combined test signal and communications service signals to a gain measurement system. The gain measurement system of the DAS is configured to receive a first measurement signal at an input node of a DAS segment among the plurality of DAS segments.

The gain measurement system is also configured to autocorrelate the first measurement signal with a test replication signal of the test signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment. The gain measurement system is also configured to receive a second measurement signal at an output node of the DAS segment. The gain measurement system is also configured to autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment. The DAS also comprises a controller. The controller is configured to subtract the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment. The controller may also be configured to adjust the gain of the DAS segment based on the measured gain of the DAS segment.

Additional features and advantages will be set forth in the detailed description which follows, and in part, will be readily apparent to those skilled in the art from the description or recognized by practicing the embodiments as described in the written description and claims hereof, as well as the appended drawings.

The accompanying drawings are included to provide a further understanding and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain the principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an exemplary distributed antenna system (DAS) capable of distributing radio frequency (RF) communications services to client devices;

FIG. **2** is a schematic diagram of an exemplary DAS comprising a plurality of DAS segments and a gain measurement system configured to measure the gain of the DAS segments during active communications of communications service signals in the DAS;

FIG. **3** is a flowchart illustrating an exemplary process of the gain measurement system in FIG. **2** measuring the gain of DAS segments during active communications employing an injected test signal having a frequency in a frequency band in the communications service signals supported by the DAS segments;

FIG. **4** is a table provided in an exemplary database in the DAS in FIG. **2** comprising correlated test measurement signal digital values to power levels to be used by the gain measurement system to correlate test measurement signals of power-related measurements of a test signal at nodes in the DAS to power levels;

FIG. **5** is schematic diagram of the exemplary DAS comprising a plurality of DAS segments in FIG. **2** and another exemplary gain measurement system configured to measure the gain of the DAS segments during active communications of communications service signals in the DAS;

FIG. **6** is a schematic diagram of an exemplary optical fiber-based DAS that can include the gain test measurement system in FIGS. **2** and **5** to measure the gain of the DAS segments during active communications of communications service signals in the DAS;

FIG. **7** is a partially schematic cut-away diagram of an exemplary building infrastructure in which the DAS in FIG. **6** can be employed; and

FIG. **8** is a schematic diagram of a generalized representation of an exemplary controller.

DETAILED DESCRIPTION

Embodiments disclosed herein include gain measurement of distributed antenna system (DAS) segments during active communications employing autocorrelation on a combined test signal and communications signal. Related devices, systems, and methods are also disclosed. In this regard, in one embodiment, a test signal is injected into one or more DAS segments in a DAS. The power of the test signal is measured at the input and output of a given DAS segment for which gain measurement is desired. The difference in power of the test signal between the input and the output of the DAS segment is the gain (or attenuation) of the DAS segment. The frequency of the test signal is provided to be within the frequency band of the communications service signals supported by the DAS segment, so that the DAS segment can transmit the frequency band of the communications service signals and can also transmit the test signal. Further, to allow for gain measurement of a DAS segment during active communication periods when the DAS segment is actively transmitting communications service signals, autocorrelation is employed to separate the test signal from combined test signal and communications service signals transmitted by the DAS segment. In this manner, gain measurements of the test signal can be obtained to determine the gain of the DAS segment even though the test signal and communications service signals are combined in the DAS segment.

In this regard, FIG. **2** is a schematic diagram of exemplary DAS segments **42**(**1**)-**42**(P) that can be provided in an exemplary DAS **40**. Note that FIG. **2** may not show an entire DAS, but portions that include the DAS segments **42**(**1**)-**42**(P). As will be discussed in more detail below, the DAS **40** includes a gain measurement system configured to measure the gain of one or more DAS segments during active communications of communications service signals in the DAS **40**. Before discussing the gain measurement system, the components of the DAS **40** in FIG. **2** will first be described below.

With reference to FIG. **2**, a plurality of DAS segments **42**(**1**)-**42**(P) are shown as included in the DAS **40**. A DAS segment **42** can be any portion of a communication path and/or a DAS component in the DAS **40** that is involved with receiving and/or distributing communication service signals. For example, the DAS **40** may be comprised of staged DAS components, such as radio interface units **44**(**1**)-**44**(Q) that are configured to receive downlink communications service signals **46**D(**1**)-**46**D(Q) from a base station or other network device (not shown) in a first DAS stage S_1 of the DAS **40**. The radio interface units **44**(**1**)-**44**(Q) are configured to receive the respective downlink communications service signals **46**D(**1**)-**46**D(Q) and distribute the downlink communications service signals **46**D(**1**)-**46**D(Q) over communication downlinks **48**(**1**)-**48**(Q) to one or more DAS components in a downstream DAS stage, which in FIG. **2** is shown as a second DAS stage S_2. Note that although the DAS **40** in FIG. **2** only illustrates the downlink communications service signals **46**D(**1**)-**46**D(Q), note that radio interface units **44**(**1**)-**44**(Q) are also configured to receive uplink communications service signals from the DAS components in the second DAS stage S_2 and distribute the uplink communications service signals to a base station or other network device (not shown). The radio interface units **44**(**1**)-**44**(Q) have associated communications service signal handling components, such as amplifiers for example, that can cause gain or attenuation to occur in the downlink communications service signals **46**D(**1**)-**46**D(Q). In this regard, the radio interface units **44**(**1**)-**44**(Q) in this example have gain control circuits **50**(**1**)-**50**(Q) that can adjust the gain of the downlink communications service signals **46**D(**1**)-**46**D(Q).

With continuing reference to FIG. **2**, the second DAS stage S_2 of the DAS **40** contains an additional DAS component **52**. The DAS component **52** receives the downlink communications service signals **46**D(**1**)-**46**D(Q) from each of the radio interface units **44**(**1**)-**44**(Q) in this example. The DAS component **52** in this example combines the downlink communications service signals **46**D(**1**)-**46**D(Q) received from the radio interface units **44**(**1**)-**44**(Q) into a combined downlink communications service signal **54**. The combined downlink communications service signal **54** is distributed by the DAS component **52** over a plurality of communication downlinks **56**(**1**)-**56**(S) to a plurality of remote units **58**(**1**)-**58**(S) in a last DAS stage S_R. For example, the remote units **58**(**1**)-**58**(S) may be remote antenna units that are each configured to distribute the combined downlink communications service signal **54** to an antenna (not shown) for wireless distribution. The DAS component **52** and remote units **58**(**1**)-**58**(S) each have associated communications service signal handling components, such as amplifiers and couplers for example, that can cause gain or attenuation to occur in the combined downlink communications service signal **54**. In this regard, the DAS component **52** and remote units **58**(**1**)-**58**(S) in this example have respective gain control circuits **60** and **62**(**1**)-**62**(S) that can adjust the gain of the combined downlink communications service signal **54**.

It may be desired to measure gain (i.e., attenuation) of one or more of the DAS segments **42**(**1**)-**42**(P) of the DAS **40** in FIG. **2** and/or the DAS components contained therein to determine performance degradation. For example, the gain of a radio interface unit **44** may be significantly different from its nominal gain level due to component variance, temperature changes, aging, and/or loading conditions. In response, the gain control circuit **50** may be adjusted to adjust the actual gain of the radio interface unit back to the desired nominal gain level. In this regard, as an example, when the DAS **40** in FIG. **2** is first installed and all elements are interconnected and operated, it may be desired to measure the gain of each relevant DAS segment **42**(**1**)-**42**(P), so that gain adjustments can be made.

In this regard, with reference to FIG. **2**, a plurality of test signal generators **64**(**1**)-**64**(Q) are provided. The plurality of test signal generators **64**(**1**)-**64**(Q) may be included in each of the radio interface units **44**(**1**)-**44**(Q), respectively, as shown in FIG. **2**. The test signal generators **64**(**1**)-**64**(Q) are each configured to inject a test signal T_S(**1**)-T_S(Q) into the respective input node **66**I(**1**)-**66**I(Q) to be combined via combiners **67**(**1**)-**67**(Q) with a respective downlink communications service signal **46**D(**1**)-**46**D(Q) to form combined signals **69**(**1**)-**69**(Q). The combiners **67**(**1**)-**67**(Q) may be included in each of the radio interface units **44**(**1**)-**44**(Q), respectively, as shown in FIG. **2**. In this manner, the downlink communications service signals **46**D(**1**)-**46**D(Q) are present so that the DAS **40** can actively handle communications services during gain measurement. The test signal T_S(**1**)-T_S(Q) has a frequency that is in a frequency band within the supported downlink communications service signals **46**D(**1**)-**46**D(Q) so that the DAS components in the DAS **40** will not filter out the test signals T_S(**1**)-T_S(Q). For example, to test the gain of the radio interface unit **44**(Q) in the first DAS segment **42**(**1**), the power of the test signal T_S(Q) is detected by a first power detection circuit **68**(Q) at the input node **66**I(Q) of the radio interface unit **44**(Q) and by a second power detection circuit **70**(Q) at output node **66**O(Q) of the radio interface unit **44**(Q). The first power detection circuits **68**(**1**)-**68**(Q) may be included in each of the radio interface units **44**(**1**)-**44**(Q), respectively, as shown in FIG. **2**. Further, the second power detection circuits **70**(**1**)-**70**(Q) may be included in each of the radio interface units **44**(**1**)-**44**(Q), respectively. The first power detection circuit **68**(Q) and the second power detection circuit **70**(Q) provide a first measurement signal **72**(Q) and second measurement signal **74**(Q), respectively. The first measurement signal **72**(Q) and second measurement signal **74**(Q) represent power-related measurements indicative of the detected power of the combined test signal T_S(Q) and downlink communications service signal **46**D(Q) at the input node **66**I(Q) and output node **66**O(Q), respectively, of the radio interface unit **44**(Q) in this example. The difference between the first measurement signal **72**(Q) and second measurement signal **74**(Q) is the gain of the radio interface unit **44**(Q). However, the first measurement signal **72**(Q) and second measurement signal **74**(Q) are measurements of a combined test signal T_S(Q) and downlink communications service signal **44**D(Q), not just the test signal T_S(Q). Thus, normal fluctuations in power that occur in the downlink communications service signal **46**D(Q) can cause the gain measurement of the radio interface unit **44**(Q) to fluctuate and not represent the true gain.

With continuing reference to FIG. **2**, note that the other DAS segments **42**(**2**)-**42**(P) also contain power detection circuits that provide a measurement signal to represent power-related measurements indicative of the detected power of the combined test signal T_S and downlink communications service signal **46**D at an input node or an output node. For example, power detection circuit **78** is coupled to an output node **80** of the DAS component **52** to provide a measurement signal **82** to represent a power-related measurement indicative of the detected power of the combined test signal T_S and downlink communications service signal **46**D at the output node **80**. The measurement signal **82** provided by the power detection circuit **78** can also be used to represent a power-related measurement indicative of the detected power of the combined test signal T_S and downlink communications service signal **46**D at the input nodes **84**(**1**)-**84**(S) of the remote units **58**(**1**)-**58**(S). A power-related measurement can be a direct measurement that indicates power, or an indirect measurement that can be translated or used to estimate power. Power detection circuits **86**(**1**)-**86**(S) can also be coupled to each of the respective output nodes **88**(**1**)-**88**(S) of the remote units **58**(**1**)-**58**(S) (**58**(**1**)-**58**(S) to provide a respective measurement signal **90**(**1**)-**90**(S) representing a power-related measurement indicative of the detected power of the combined test signal T_S and downlink communications service signal **46**D at the output nodes **88**(**1**)-**88**(S) of the remote units **58**(**1**)-**58**(S). In summary, by providing power detection circuits coupled to each input and output node of the DAS components in the DAS **40**, gain of any DAS segment **42**(**1**)-**42**(P) or any combination thereof can be measured.

In this regard, to allow for gain measurement of any DAS segment **42**(**1**)-**42**(P) or combination thereof in the DAS **40** in FIG. **2** during active communication periods, autocorrelation is employed to separate the test signals T_S(**1**)-T_S(Q) from combined test signals T_S(**1**)-T_S(Q) and respective downlink communications service signals **46**D(**1**)-**46**D(Q). In this manner, gain measurements can be obtained of the test signals T_S(**1**)-T_S(Q) to determine the gain of the desired DAS segment **42**(**1**)-**42**(P) even though the test signals T_S(**1**)-T_S(Q) and the downlink communications service signals **46**D(**1**)-**46**D(Q) are combined in the DAS segments **42**(**1**)-**42**(P) during gain measurement operations. Further, the autocorrelation examples discussed below can be employed to separate the test signals T_S(**1**)-T_S(Q) from combined test signals T_S(**1**)-T_S(Q) even though the test signals T_S(**1**)-T_S(Q) may have significantly lower amplitude or power levels than the downlink communications service signals **46**D(**1**)-**46**D(Q). For example, the test signal generators **64**(**1**)-**64**(Q) may be configured to inject the test signals T_S(**1**)-T_S(Q) at significantly lower amplitudes or power levels than the downlink communications service signals **46**D(**1**)-**46**D(Q) to reduce or avoid interference between the test signals T_S(**1**)-T_S(Q) and the downlink communications service signals **46**D(**1**)-**46**D(Q).

In this regard, the DAS **40** in FIG. **2** includes a DAS segment gain measurement system **92**. The DAS segment gain measurement system **92** includes a signal correlator **94** to separate a test signal T_S from a downlink communications service signal **46**D. Note that the signal correlator **94** may be a dedicated circuit or may be implemented in a controller, such as a microprocessor, as examples. In the example above, the signal correlator **94** can be configured to receive a measurement signal **72**, **74**, **82**, **90** from a power detection circuit **68**, **70**, **78**, **86**. The signal correlator **94** is also configured to receive a test replication signal T_{SR} that replicates a test signal T_S generated by a test signal generator **64**. The signal correlator **94** in this example is configured to autocorrelate a received measurement signal **72**, **74**, **82**, **90** with the test replication signal T_{SR} to separate out the downlink communications service signal **46**D and generate a test measurement signal **96** indicative of the power in the test signal T_S component of the received measurement signal **72**, **74**, **82**, **90**. Autocorrelation is the cross-correlation of a signal with itself to observe similarities as a function of time lag. Autocorrelation is a mathematical tool that can be used for finding repeating patterns, such as the presence of a periodic signal, which in this example the test replication signal T_{SR}, obscured by noise or other signal, which in this example would be the downlink communications service signal **46**D.

With continuing reference to FIG. **2**, the test measurement signal **96** can then be provided to a controller **98**. If the signal correlator **94** is provided as part of the controller **98**, the test measurement signal **96** is an internal signal or value of the test measurement indicative of the power in the test signal T_S component of the received measurement signal **72**, **74**, **82**, **90**. Thus, to measure gain of a particular DAS segment **42**(**1**)-**42**(P), at least two (i.e., a first and second) measurement signals **72**, **74**, **82**, **90** are provided to the signal correlator **94**. In this manner, the signal correlator **94** can provide two test measurement signals **96**(**1**), **96**(**2**), one for an input node and another for an output node, to the controller **98**. The controller **98** receives the first and second test measurement signals **96**(**1**), **96**(**2**) and subtracts the first test measurement signal **96**(**1**) from the second test measurement signals **96**(**2**) to determine a gain of the measured DAS segment **42**(**1**)-**42**(P). As one non-limiting example, the controller **98** can then generate the gain control signal **100** to be communicated to an appropriate gain control circuit **50**(**1**)-**50**(Q), **60**, **62**(**1**)-**62**(S) of a DAS component to adjust the gain therein, as desired or needed.

To further explain an exemplary operation of the gain measurement system **92** in the DAS **40** of FIG. **2**, the flowchart in FIG. **3** is provided. FIG. **3** is a flowchart illustrating an exemplary process **102** of the gain measurement system **92** in FIG. **2** measuring the gain of selected DAS segments **42**(**1**)-**42**(P) during active communications. As discussed above, the controller **98** directs the desired test signal generator(s) **64**(**1**)-**64**(Q) to inject the test signal T_S into the respective downlink communications service signal **46**D(**1**)-**46**D(Q). The corresponding power detection circuits **68**(**1**)-**68**(Q), **70**(**1**)-**70**(Q), **82**, or **86**(**1**)-**86**(S) provide a respective measurement signal **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S). As provided in FIG. **3**, the signal correlator **94** receives the first measurement signal **72**, **74**, or **82** of a desired input node **66**I, **66**O, or **84** of the DAS segment **42** (block **104**). The signal correlator **94** receives the test replication signal TSR (block **106**). The signal correlator **94** autocorrelates the first measurement signal **72**, **74**, or **82** with the test replication signal TSR to retrieve the first test measurement signal **96**(**1**) indicative of the power in the test signal Ts at an input node **66**I, **66**O, or **84** of the desired DAS segment **42** (block **108**). The signal correlator **94** in this example also later receives the second measurement signal **74**, **82**, or **90** of a desired output node **66**O, **80**, or **88** of the DAS segment **42** (block **110**). The signal correlator **94** autocorrelates the second measurement signal **74**, **82**, or **90** with the test replication signal TSR to retrieve the second test measurement signal **96**(**2**) indicative of the power in the test signal Ts at an output node **66**O, **80**, or **88** of the desired DAS segment **42** (block **112**).

With continuing reference to FIG. **3**, the controller **98** receives and subtracts the first test measurement signal **96**(**1**) from the second test measurement signal **96**(**2**) to determine a measured gain of the selected DAS segment **42** (block **114**). The controller **98** can then optionally send a gain control signal **100** to the appropriate gain control circuit **50**(**1**)-**50**(Q), **60**, **62**(**1**)-**62**(S) of a DAS component to adjust the gain therein, as desired or needed (block **116**), and the process ends (block **118**). The process **102** can be initiated or repeated as desired, because as discussed above, the correlation methods provided in the DAS segment gain measurement system **92** allow gain measurements when the DAS **40** is active or not actively distributing communications service signals.

With reference back to the DAS **40** in FIG. **2**, note that the controller **98** is provided in the DAS segment gain measurement system **92** as a standalone controller. However, the controller **98** that receives the test measurement signal **96** from the signal correlator **94** could be provided as part of another DAS component, for example, a radio interface unit **44** or the second DAS component **52** as examples. The controller **98** could also be provided as part of a central unit not shown in which the radio interface units **44**(**1**)-**44**(Q) and/or the second DAS component **52** are physically disposed.

Further with reference to the DAS **40** in FIG. **2**, note that in this example, the power detection circuits **68**(**1**)-**68**(Q) each include a power detector **120**(**1**)-**120**(Q) and analog-to-digital converters (ADC) **122**(**1**)-**122**(Q). Similarly, the other power detection circuits **70**(**1**)-**70**(Q), **78**, **86**(**1**)-**86**(S) include respective power detectors **124**(**1**)-**124**(Q), **128**, **132**(**1**)-**132**(S) and ADCs **126**(**1**)-**126**(Q), **130**, **134**(**1**)-**134**(S). The ADCs **126**(**1**)-**126**(Q), **130**, **134**(**1**)-**134**(S) are configured to sample the measurement signals provided by the power detection circuit **70**(**1**)-**70**(Q), **78**, **86**(**1**)-**86**(S) and provide the measurement signals **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) as digital power measurement signals to the DAS segment gain measurement system **92**. In this example, the signal correlator **94** is configured to correlate the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) as digital signals with the replication test signal TSR to generate the test measurement signal **96**. As another non-limiting example, the ADC elements **122** may also be physically located inside the controller **98** system or component.

Further, the power detectors **120**(**1**)-**120**(Q), **124**(**1**)-**124**(Q), **128**, **132**(**1**)-**132**(S) and ADCs **122**(**1**)-**122**(Q), **126**(**1**)-**126**(Q), **130**, **134**(**1**)-**134**(S) may be configured to not actually detect power in a combined signal **69**, but rather the voltage level as a power-related indication. Thus, the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) would represent voltage level measurements in this example. In this example, the controller **98** could be configured to correlate the voltage level measurements in the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) to a power measurement. For example, if the controller **98** was aware of the impedance Z of the node of the DAS segment **42** in which the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) originated, the controller **98** could convert the voltage level measurement of the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) according to the formula $Power=Vi^2/Zi$, where Vi is equal to the voltage measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S), and Zi is the impedance of the node of the DAS segment **42**. Alternatively, the controller **98** could employ a conversion database **136** like provided in FIG. **4** as an example, wherein the digital value of a digital measurement signal **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) could be used to look-up a digital value **137** in the conversion database **136**. The power level **138** represented by the digital measurement signal **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) could then be determined from a corresponding power level stored in a voltage level, power level pair in the conversion database **136**.

In the DAS segment gain measurement system **92** in the DAS segments **42**(**1**)-**42**(P) in FIG. **2**, only one signal correlator **94** is provided. Thus, the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) must be provided to the DAS segment gain measurement system **92** with timing that does not cause interference between any of the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) for an input node and an output node of a DAS segment **42** for gain to be measured. However, it is possible to provide a gain measurement system with two signal correlators **94** to avoid the potential for interference in received measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S).

In this regard, FIG. **5** is schematic diagram of the DAS segments **42**(**1**)-**42**(P) in FIG. **2**, but with an alternative DAS segment gain measurement system **92**(**1**). In this embodiment, a first signal correlator **94**(**1**) and a second signal correlator **94**(**2**) are provided in the DAS segment gain measurement system **92**(**1**). Both the first signal correlator **94**(**1**) and the second signal correlator **94**(**2**) are configured to operate just as the signal correlator **94** in the DAS segment gain measurement system **92** in FIG. **2**. However, the first signal correlator **94**(**1**) and the second signal correlator **94**(**2**) are each configured to separately provide their respective test measurement signals **96**(**1**), **96**(**2**) to the controller **98**. A signal switch **139** is provided that is configured to receive each of the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) from the power detection circuits **68**(**1**)-**68**(Q), **70**(**1**)-**70**(Q), **78**, **86**(**1**)-**86**(S) and switch one of the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) for an input node of a DAS segment **42** to the first signal correlator **94**(**1**) and another of the measurement signals **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) for an output node of a DAS segment **42** to the second signal correlator **94**(**2**). In this manner, each of the first and second signal correlators **94**(**1**), **94**(**2**) can autocorrelate their respective received measurement signal **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) with the replication test signal T_{SR} to provide the first and second test measurement signals **96**(**1**), **96**(**2**) to the controller **98** without interfering with each other. The signal switch **139** may be under control of the controller **98** or other controller to select which DAS segment **42** will be measured for gain, by selecting the appropriate measurement signal **72**(**1**)-**72**(Q), **74**(**1**)-**74**(Q), **82**, **90**(**1**)-**90**(S) to provide to the first and second signal correlators **94**(**1**), **94**(**2**).

The gain measurement systems disclosed herein can be provided in other DASs other than DAS **40** in FIGS. **2** and **5**, respectively. For example, FIG. **6** is a schematic diagram of another exemplary optical fiber-based DAS **140** that may be include the gain measurement systems **92**, **92**(**1**) discussed above. In this embodiment, the optical fiber-based DAS **140** includes optical fiber for distributing communications services. The optical fiber-based DAS **140** in this embodiment is comprised of three (3) main components. One or more radio interfaces provided in the form of radio interface modules (RIMs) **142**(**1**)-**142**(M) in this embodiment are provided in a central unit **44** to receive and process downlink electrical communications signals **146**D(**1**)-**146**D(R) prior to optical conversion into downlink optical communications signals. The RIMs **142**(**1**)-**142**(M) provide both downlink and uplink interfaces. The notations "1-R" and "1-M" indicate that any number of the referenced component, 1-R and 1-M, respectively, may be provided. The central unit **144** is configured to accept the plurality of RIMs **142**(**1**)-**142**(M) as modular components that can easily be installed and removed or replaced in the central unit **144**. In one embodiment, the central unit **144** is configured to support up to twelve (12) RIMs **142**(**1**)-**142**(**12**).

Each RIM **142**(**1**)-**142**(M) can be designed to support a particular type of radio source or range of radio sources (i.e., frequencies) to provide flexibility in configuring the central unit **144** and the optical fiber-based DAS **140** to support the desired radio sources. For example, one RIM **142** may be configured to support the Personal Communication Services (PCS) radio band. Another RIM **142** may be configured to support the 700 MHz radio band. In this example, by inclusion of these RIMs **142**, the central unit **144** could be configured to support and distribute communications signals on both PCS and LTE 700 radio bands, as an example. RIMs **142** may be provided in the central unit **144** that support any frequency bands desired, including but not limited to the US Cellular band, Personal Communication Services (PCS) band, Advanced Wireless Services (AWS) band, 700 MHz band, Global System for Mobile communications (GSM) 900, GSM 1800, and Universal Mobile Telecommunication System (UMTS). The RIMs **142** may also be provided in the central unit **144** that support any wireless technologies desired, including but not limited to Code Division Multiple Access (CDMA), CDMA200, 1xRTT, Evolution-Data Only (EV-DO), UMTS, High-speed Packet Access (HSPA), GSM, General Packet Radio Services (GPRS), Enhanced Data GSM Environment (EDGE), Time Division Multiple Access (TDMA), Long Term Evolution (LTE), iDEN, and Cellular Digital Packet Data (CDPD).

The RIMs **142** may be provided in the central unit **144** that support any frequencies desired, including but not limited to US FCC and Industry Canada frequencies (824-849 MHz on uplink and 869-894 MHz on downlink), US FCC and Industry Canada frequencies (1850-1915 MHz on uplink and 1930-1995 MHz on downlink), US FCC and Industry Canada frequencies (1710-1755 MHz on uplink and 2110-2155 MHz on downlink), US FCC frequencies (698-716 MHz and 776-787 MHz on uplink and 728-746 MHz on downlink), EU R & TTE frequencies (880-915 MHz on uplink and 925-960 MHz on downlink), EU R & TTE frequencies (1710-1785 MHz on uplink and 1805-1880 MHz on downlink), EU R & TTE frequencies (1920-1980 MHz on uplink and 2110-2170 MHz on downlink), US FCC frequencies (806-824 MHz on uplink and 851-869 MHz on downlink), US FCC frequencies (896-901 MHz on uplink and 929-941 MHz on downlink), US FCC frequencies (793-805 MHz on uplink and 763-775 MHz on downlink), and US FCC frequencies (2495-2690 MHz on uplink and downlink).

The downlink electrical communications signals **146**D(**1**)-**146**D(R) are provided to a plurality of optical interfaces provided in the form of optical interface modules (OIMs) **148**(**1**)-**148**(N) in this embodiment to convert the downlink electrical communications signals **146**D(**1**)-**146**D(R) into downlink optical communications signals **150**D(**1**)-**150**D(R). The notation "1-N" indicates that any number of the referenced component 1-N may be provided. The OIMs **148** may be configured to provide one or more optical interface components (OICs) that contain optical to electrical (0/E) and electrical to optical (E/O) converters, as will be described in more detail below. The OIMs **148** support the radio bands that can be provided by the RIMs **142**, including the examples previously described above. Thus, in this embodiment, the OIMs **148** may support a radio band range from 400 MHz to 2700 MHz, as an example.

The OIMs **148(1)**-**148**(N) each include E/O converters to convert the downlink electrical communications signals **146**D(**1**)-**146**D(R) into the downlink optical communications signals **150**D(**1**)-**150**D(R). The downlink optical communications signals **150**D(**1**)-**150**D(R) are communicated over downlink optical fiber(s) **152**D to a plurality of remote antenna units **154(1)**-**154**(P). The notation "1-P" indicates that any number of the referenced component 1-P may be provided. O/E converters provided in the remote antenna units **154(1)**-**154**(P) convert the downlink optical communications signals **150**D(**1**)-**150**D(R) back into the downlink electrical communications signals **146**D(**1**)-**146**D(R), which are provided to antennas **158(1)**-**158**(P) in the remote antenna units **154(1)**-**154**(P) to client devices in the reception range of the antennas **158(1)**-**158**(P).

E/O converters are also provided in the remote antenna units **154(1)**-**154**(P) to convert uplink electrical communications signals **160**U(**1**)-**160**U(P) received from client devices through the antennas **158(1)**-**158**(P) into uplink optical communications signals **150**U(**1**)-**150**U(P) to be communicated over uplink optical fibers **152**U to the OIMs **148(1)**-**148**(N). The OIMs **148(1)**-**148**(N) include O/E converters that convert the uplink optical communications signals **150**U(**1**)-**150**U(P) into uplink electrical communications signals **162**U(**1**)-**162**U(P) that are processed by the RIMs **142(1)**-**142**(M) and provided as uplink electrical communications signals **162**U(**1**)-**162**U(P).

The DAS **140** in FIG. **6** may also be provided in an indoor environment, as illustrated in FIG. **7**. FIG. **7** is a partially schematic cut-away diagram of a building infrastructure **170** employing the DASs **40**, **140** described herein. The building infrastructure **170** in this embodiment includes a first (ground) floor **172(1)**, a second floor **172(2)**, and a third floor **172(3)**. The floors **172(1)**-**172(3)** are serviced by the central unit **174** to provide the antenna coverage areas **176** in the building infrastructure **170**. The central unit **174** is communicatively coupled to the base station **178** to receive downlink communications signals **180**D from the base station **178**. The central unit **174** is communicatively coupled to the remote antenna units **182** to receive the uplink communications signals **180**U from the remote antenna units **182**, as previously discussed above. The downlink and uplink communications signals **180**D, **180**U communicated between the central unit **174** and the remote antenna units **182** are carried over a riser cable **184**. The riser cable **184** may be routed through interconnect units (ICUs) **186(1)**-**186(3)** dedicated to each floor **172(1)**-**172(3)** that route the downlink and uplink communications signals **180**D, **180**U to the remote antenna units **182** and also provide power to the remote antenna units **182** via array cables **188**.

FIG. **8** is a schematic diagram representation of additional detail illustrating a computer system **190** that could be employed in a gain measurement system as a controller or other control means to measure gain of a DAS segment **42**. The control system **190** is adapted to execute instructions from an exemplary computer-readable medium to perform these and/or any of the functions or processing described herein.

In this regard, the computer system **190** in FIG. **8** may include a set of instructions that may be executed to calculate gain of DAS segment in a DAS. The computer system **190** may be connected (e.g., networked) to other machines in a LAN, an intranet, an extranet, or the Internet. While only a single device is illustrated, the term "device" shall also be taken to include any collection of devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. The computer system **190** may be a circuit or circuits included in an electronic board card, such as, a printed circuit board (PCB), a server, a personal computer, a desktop computer, a laptop computer, a personal digital assistant (PDA), a computing pad, a mobile device, or any other device, and may represent, for example, a server or a user's computer.

The exemplary computer system **190** in this embodiment includes a processing device or processor **192**, a main memory **194** (e.g., read-only memory (ROM), flash memory, dynamic random access memory (DRAM), such as synchronous DRAM (SDRAM), etc.), and a static memory **196** (e.g., flash memory, static random access memory (SRAM), etc.), which may communicate with each other via a data bus **198**. Alternatively, the processor **192** may be connected to the main memory **194** and/or static memory **196** directly or via some other connectivity means. The processor **192** may be a controller, and the main memory **194** or static memory **196** may be any type of memory.

The processor **192** represents one or more general-purpose processing devices, such as a microprocessor, central processing unit, or the like. More particularly, the processor **192** may be a complex instruction set computing (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a processor implementing other instruction sets, or other processors implementing a combination of instruction sets. The processor **192** is configured to execute processing logic in instructions for performing the operations and steps discussed herein.

The computer system **190** may further include a network interface device **200**. The computer system **190** also may or may not include an input **202**, configured to receive input and selections to be communicated to the system **190** when executing instructions. The system **190** also may or may not include an output **204**, including but not limited to a display, a video display unit (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)), an alphanumeric input device (e.g., a keyboard), and/or a cursor control device (e.g., a mouse).

The computer system **190** may or may not include a data storage device that includes instructions **208** stored in a computer-readable medium **210**. The instructions **208** may also reside, completely or at least partially, within the main memory **194** and/or within the processor **192** during execution thereof by the system **190**, the main memory **194** and the processor **192** also constituting computer-readable medium. The instructions **208** may further be transmitted or received over a network **212** via the network interface device **200**.

While the computer-readable medium **210** is shown in an exemplary embodiment to be a single medium, the term "computer-readable medium" shall include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions, or any medium that is capable of storing, encoding, or carrying a set of instructions for execution by the processing device and that cause the processing device to perform any one or more of the methodologies of the embodiments disclosed herein, or solid-state memories, optical medium, and magnetic medium.

The embodiments disclosed herein include various steps. The steps of the embodiments disclosed herein may be formed by hardware components or may be embodied in machine-executable instructions, which may be used to cause a general-purpose or special-purpose processor programmed with the instructions to perform the steps. Alternatively, the steps may be performed by a combination of hardware and software.

The embodiments disclosed herein may be provided as a computer program product, or software, that may include a machine-readable medium (or computer-readable medium) having stored thereon instructions, which may be used to program a computer system (or other electronic devices) to perform a process according to the embodiments disclosed herein. A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes: a machine-readable storage medium (e.g., ROM, random access memory ("RAM"), a magnetic disk storage medium, an optical storage medium, flash memory devices, etc.); and the like.

Unless specifically stated otherwise and as apparent from the previous discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing," "computing," "determining," "displaying," or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data and memories represented as physical (electronic) quantities within the computer system's registers into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission, or display devices.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatuses to perform the required method steps. The required structure for a variety of these systems will appear from the description above. In addition, the embodiments described herein are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the embodiments as described herein.

Those of skill in the art will further appreciate that the various illustrative logical blocks, modules, circuits, and algorithms described in connection with the embodiments disclosed herein may be implemented as electronic hardware, instructions stored in memory or in another computer-readable medium and executed by a processor or other processing device, or combinations of both. The components of the distributed antenna systems described herein may be employed in any circuit, hardware component, integrated circuit (IC), or IC chip, as examples. Memory disclosed herein may be any type and size of memory and may be configured to store any type of information desired. To clearly illustrate this interchangeability, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. How such functionality is implemented depends on the particular application, design choices, and/or design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present embodiments.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments may be implemented or performed with a processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. Furthermore, a controller may be a processor. A processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

The embodiments disclosed herein may be embodied in hardware and in instructions that are stored in hardware, and may reside, for example, in RAM, flash memory, ROM, Electrically Programmable ROM (EPROM), Electrically Erasable Programmable ROM (EEPROM), registers, a hard disk, a removable disk, a CD-ROM, or any other form of computer-readable medium known in the art. An exemplary storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a remote station. In the alternative, the processor and the storage medium may reside as discrete components in a remote station, base station, or server.

The operational steps described in any of the embodiments herein are described to provide examples and discussion. The operations described may be performed in numerous different sequences other than the illustrated sequences. Operations described in a single operational step may actually be performed in a number of different steps. One or more operational steps discussed in the exemplary embodiments may be combined.

Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that any particular order be inferred.

Various modifications and variations can be made without departing from the spirit or scope of the invention. Since modifications combinations, sub-combinations and variations of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and their equivalents.

What is claimed is:

1. A distributed antenna system (DAS) segment gain measurement system, comprising:

a signal correlator configured to:

receive a first measurement signal comprising a power-related measurement of a combined test signal and communications service signal at an input node of a DAS segment, the combined test signal of a frequency in a frequency band of the communications service signal;

receive a test replication signal indicative of the test signal;

autocorrelate the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment;

provide the first test measurement signal at the input node to a controller;

receive a second measurement signal comprising a power-related measurement of the combined test signal at an output node of the DAS segment;

autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment;

provide the second test measurement signal at the input node to a controller;

a controller configured to:

receive the first test measurement signal;

receive the second test measurement signal; and

subtract the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment.

2. The DAS segment gain measurement system of claim **1**, wherein the controller is further configured to adjust the gain of the DAS segment based on the measured gain of the DAS segment.

3. The DAS segment gain measurement system of claim **1**, wherein the controller comprises the signal correlator.

4. The DAS segment gain measurement system of claim **1**, further comprising:

a first power detection circuit comprising a first power detector coupled to the input node of the DAS segment, the first power detector configured to:

detect the power in the combined test signal at the input node of the DAS segment; and

provide the first measurement signal indicative of the detected power in the combined test signal at the input node of the DAS segment; and

a second power detection circuit comprising a second power detector coupled to the output node of the DAS segment, the second power detector configured to:

detect the power in the combined test signal at the output node of the DAS segment; and

provide the second measurement signal indicative of the detected power in the combined test signal at the output node of the DAS segment.

5. The DAS segment gain measurement system of claim **4**, further comprising:

a first analog-to-digital converter (ADC) configured to sample the first measurement signal to provide the first measurement signal comprising a digital first measurement signal; and

a second analog-to-digital converter (ADC) configured to sample the second measurement signal to provide the second measurement signal comprising a digital second measurement signal.

6. The DAS segment gain measurement system of claim **1**, further comprising a test signal generator configured to:

generate the test signal; and

inject the test signal to the input node of the DAS segment.

7. The DAS segment gain measurement system of claim **1**, wherein the signal correlator further comprises:

a first signal correlator configured to:

autocorrelate the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment; and

provide the first test measurement signal to the controller;

a second signal correlator configured to:

autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment; and

provide the first test measurement signal to the controller;

a signal switch configured to:

receive the first measurement signal;

receive the second measurement signal;

switch the first measurement signal to be provided to the first signal correlator; and

switch the second measurement signal to be provided to the second signal correlator.

8. The DAS segment gain measurement system of claim **1**, wherein:

the power-related measurement of the combined test signal and communications service signal at the input node of the DAS segment comprises a voltage measurement of the combined test signal and communications service signal at the input node of the DAS segment; and

the power-related measurement of the combined test signal and communications service signal at the output node of the DAS segment comprises a voltage measurement of the combined test signal and the communications service signal at the output node of the DAS segment.

9. The DAS segment gain measurement system of claim **8**, wherein the controller is further configured to:

convert the voltage measurement of the first test measurement signal to a first power test measurement signal; and

convert the voltage measurement of the second test measurement signal to a second power test measurement signal;

the controller configured to:

subtract the first power test measurement signal from the second power test measurement signal to determine a measured power gain of the DAS segment; and

adjust the gain of the DAS segment based on the measured power gain of the DAS segment.

10. The DAS segment gain measurement system of claim **9**, further comprising:

a database comprising pre-calibrated correlated voltage measurement to power measurement data pairs;

wherein the controller is configured to:

convert the voltage measurement of the first test measurement signal to the first power test measurement signal by selecting the power measurement in a voltage measurement to power measurement data pair in the database corresponding to the voltage measurement of the first test measurement signal; and

convert the voltage measurement of the second test measurement signal to the second power test measurement signal by selecting the power measurement in a voltage measurement to power measurement data pair in the database corresponding to the voltage measurement of the second test measurement signal.

11. The DAS segment gain measurement system of claim **9**, further comprising:

wherein the controller is configured to:

convert the voltage measurement of the first test measurement signal to the first power test measurement signal by calculating power according to $P=Vi^2/Zi$, where Vi is equal to the voltage measurement of the first test measurement signal, and Zi is the impedance at the input node of the DAS segment; and

convert the voltage measurement of the second test measurement signal to the second power test measurement signal by calculating power according to $P=Vo^2/Zo$, where Vo is equal to the voltage measurement of the second test measurement signal, and Zo is the impedance at the output node of the DAS segment.

12. The DAS segment gain measurement system of claim 1, wherein the DAS segment includes at least one of a remote antenna unit and a radio interface unit.

13. The DAS segment gain measurement system of claim 1, wherein the DAS segment includes an optical interface module.

14. A method of measuring gain in a distributed antenna system (DAS) segment, comprising:
receiving a first measurement signal comprising a power-related measurement of a combined test signal and communications service signal at an input node of a DAS segment, the combined test signal of a frequency in a frequency band of the communications service signal;
receiving a test replication signal indicative of the test signal;
autocorrelating the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment;
receiving a second measurement signal comprising a power-related measurement of the combined test signal at an output node of the DAS segment;
autocorrelating the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment; and
subtracting the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment.

15. The method of claim 14, further comprising adjusting the gain of the DAS segment based on the measured gain of the DAS segment.

16. The method of claim 14, further comprising:
detecting the power in the combined test signal at the input node of the DAS segment;
providing the first measurement signal indicative of the detected power in the combined test signal at the input node of the DAS segment;
detecting the power in the combined test signal at the output node of the DAS segment; and
providing the second measurement signal indicative of the detected power in the combined test signal at the output node of the DAS segment.

17. The method of claim 14, further comprising:
sampling the first measurement signal to provide a first digital measurement signal; and
sampling the second measurement signal to provide second digital measurement signal; and
comprising:
autocorrelating the first digital measurement signal with the test replication signal to retrieve a first digital test measurement signal indicative of the power in the test signal at the input node of the DAS segment;
autocorrelating the second digital measurement signal with the test replication signal to retrieve a second digital test measurement signal indicative of the power in the test signal at the output node of the DAS segment;
subtracting the first digital test measurement signal from the second digital test measurement signal to determine a measured gain of the DAS segment; and
adjusting the gain of the DAS segment based on the measured gain of the DAS segment.

18. The method of claim 14, further comprising:
generating the test signal; and
injecting the test signal to the input node of the DAS segment.

19. The method of claim 14, wherein:
the power-related measurement of the combined test signal and the communications service signal at the input node of the DAS segment comprises a voltage measurement of the combined test signal and the communications service signal at the input node of the DAS segment; and
the power-related measurement of the combined test signal and the communications service signal at the output node of the DAS segment comprises a voltage measurement of the combined test signal and the communications service signal at the output node of the DAS segment.

20. The method of claim 19, further comprising:
converting the voltage measurement of the first test measurement signal to a first power test measurement signal; and
converting the voltage measurement of the second test measurement signal to a second power test measurement signal; and
wherein:
subtracting the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment comprises subtracting the first power test measurement signal from the second power test measurement signal to determine a measured power gain of the DAS segment; and
adjusting the gain of the DAS segment based on the measured gain of the DAS segment comprises adjusting the gain of the DAS segment based on the measured power gain of the DAS segment.

21. A distributed antenna system (DAS), comprising:
a plurality of DAS segments each configured to distribute communications service signals by being configured to distribute downlink communications service signals towards a plurality of remote antenna units and distribute uplink communications service signals received from client devices towards a central unit;
the plurality of DAS segments each comprising an input node and an output node;
a test signal generator configured to:
generate a test signal of a frequency in a frequency band of the communications service signals; and
inject the test signal to the input node of the plurality of DAS segments;
a plurality of power detection circuits each coupled to an input node or an output node of a DAS segment, each of the plurality of power detection circuits configured to:
detect a power-related measurement of combined test signal and communications service signal; and
provide a measurement signal comprising a power-related measurement of a combined test signal and communications service signal;
a signal switch configured to:
receive a plurality of the measurement signals from each of the plurality of power detection circuits; and
selectively provide a measurement signal from a plurality of the power-related measurements of the combined test signal and communications service signals to a gain measurement system;
the gain measurement system configured to:
receive a first measurement signal at an input node of a DAS segment among the plurality of DAS segments;
autocorrelate the first measurement signal with a test replication signal of the test signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment;

receive a second measurement signal at an output node of the DAS segment;

autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment; and

a controller configured to subtract the first test measurement signal from the second test measurement signal to determine a measured gain of the DAS segment.

22. The DAS of claim **21**, wherein the controller is further configured to adjust the gain of the DAS segment based on the measured gain of the DAS segment.

23. The DAS of claim **21**, wherein the gain measurement system comprises:

a first signal correlator configured to:

autocorrelate the first measurement signal with the test replication signal to retrieve a first test measurement signal indicative of the power in the test signal at the input node of the DAS segment; and

provide the first test measurement signal to the controller;

a second signal correlator configured to:

autocorrelate the second measurement signal with the test replication signal to retrieve a second test measurement signal indicative of the power in the test signal at the output node of the DAS segment; and

provide the second test measurement signal to the controller;

the signal switch configured to:

receive the first measurement signal;

receive the second measurement signal;

selectively provide the first measurement signal to be provided to the first signal correlator; and

selectively provide the second measurement signal to be provided to the second signal correlator.

24. The DAS of claim **21**, further comprising an analog-to-digital converter (ADC) configured to sample the measurement signal to provide the measurement signal comprising a first digital measurement signal.

25. The DAS of claim **21**, wherein each of the measurement signals from the plurality of power detection circuits comprises a voltage measurement of the combined test signal and the communications service signal at the input node of the DAS segment.

26. The DAS of claim **25**, wherein the controller is further configured to:

convert the voltage measurement of the first test measurement signal to a first power test measurement signal; and

convert the voltage measurement of the second test measurement signal to a second power test measurement signal;

the controller configured to:

subtract the first power test measurement signal from the second power test measurement signal to determine a measured power gain of the DAS segment; and

adjust the gain of the DAS segment based on the measured power gain of the DAS segment.

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